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creation of a weather-based forecasting model for *Lipaphis erysimi* kalt, the mustard aphid. in Uttarakhand's Tarai area

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Research Article

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ABSTRACT

In India, infestations of *Lipaphis erysimi* (Kalt.) cause considerable yield losses in mustard. The impact of weather on mustard aphid incidence and development was investigated using sixteen years' worth of experimental data. Aphid population growth and arrival were shown to be regulated by temperature. The impact of weather factors one week before to the aphid population measurement is greater than that on the same date, two weeks prior, and three weeks prior. In the current study, a forecasting model for *L. erysimi* and control measures may be developed utilizing a regression equation between aphid incidence and meteorological data from the previous week.

Keywords: mustard, aphids, weather parameters, forecasting models, and regression techniques.

INTRODUCTION

India's social security and general economic well-being are significantly influenced by the agriculture industry. After cereals, oilseed crops are the second most significant factor influencing the agricultural economy. After the United States, China, Brazil, and Argentina, India has the fifth-largest vegetable oil economy in the world, accounting for 7.4% of global oilseed production, 6.1% of oil meal production, 3.9% of global oil meal exports, 5.8% of vegetable oil production, 11.2% of global oil imports, and 9.3% of global edible oil consumption. Over 80% of the land is planted with oilseeds during the Rabi season, with rapeseed-mustard being the primary crop (Patel et al., 2017). Its environmental sensitivity—that is, the instability of the mustard plant under various environmental conditions—is regarded as the most important of the abiotic elements. Better pest control may result from an understanding of the dynamics of pest populations in response to meteorological conditions (Patel and Singh, 2017). Pest weather models may be created using long-term data on pest infestation and meteorological conditions in a certain location. These models can subsequently be used for agro-ecological pest zoning. The relationship between pest populations and current or one or two lag weeks' meteorological conditions is the basis for forecasting models. However, the meteorological conditions of a few weeks or months before may determine the peak pest occurrence within a season. For proper and current planning, particularly in the unpredictable field of agriculture, accurate and timely predictions are essential. The output of rapeseed mustard will be seriously threatened by the dynamics of illnesses and insect pests. Pest population dynamics are caused by both biotic and abiotic causes (Singh et al., 2009). The insect population epidemic is significantly influenced by environmental factors as temperature, rainfall, daylight hours, and relative humidity (Siswanto, Dzolkhifli, and Elna, 2008). The only variables influencing pest population density are the weather conditions in the weeks or months before. Therefore, it becomes necessary to determine how the pest population is related to the meteorological conditions of a few weeks before. To guarantee prompt readiness to confront upcoming pest issues and avoid output losses, it is crucial to understand the seasonal incidence and population growth tendency (Das et al., 2008). In light of this, the current study was conducted to develop and verify a weather-based forecasting model for Uttarakhand, India's Tarai area.

MATERIALS AND METHODS

Multiple regressions based on correlation coefficients between the dependent variables under investigation and the corresponding weather parameter in various weeks were appropriate for forecasting models based on weather factors as independent variables at the time of the first arrival of aphids on mustard as dependent variables. The Tarai area of Uttarakhand's eighteen-year history, from 1998–1999 to 2014–2015, was gathered from India. Weather data for sixteen years was organized by week according to various characteristics, from the beginning of the aphid population until its migration. The model was developed using a typical week for every year. Square root transformed data were utilized in the investigation to normalize the aphid population. From the beginning of the aphid population until the week of the peak aphid population, the square root transformed peak mustard aphid population across the years was connected with weekly values of each meteorological parameter independently. This

allowed for the identification of the most significant week in respect to several meteorological factors that affected the aphid population. A multiple linear pest-weather model was created using the values of each weather parameter for the most significant week so determined. Two years of independent data on meteorological factors and the number of mustard aphids, which were not utilized in the model's development, were used to verify the model. The creation of the model did not make use of this data. The actual and anticipated aphid populations were compared in order to assess the model's performance.

RESULTS AND DISCUSSION

Regression equations with a high coefficient of determination, low error, and test of statistical significance were employed to forecast the initial arrival of the aphid population. R² and standard error have been used to construct and test important equations. In comparison to the observed data of the experimental years 2015–16 and 2016–17, it was discovered that the multiple linear equation developed for the weather data observation one week prior to peak aphid population had a higher R² (0.71) with standard error 2.72, but predicted the same population of aphids with corresponding weather conditions (Table 1). The following pest-weather model was developed between *L. erysimi* (Kalt.), the mustard aphid, and all meteorological factors (Equation 2, Table 1).

$$Y = 31.58 + 2.08T_{MAX} - 2.76T_{MIN} - 0.87RH1 + 0.65RH2 - 0.03RF - 1.50SS + 2.13$$

70% of the variability in *L. erysimi* was explained by WSWeather factors ($p = 0.08$). However, the coefficient of determination ($R^2 = 0.49$) reduced when WS (wind speed) was removed, demonstrating a substantial impact of WS on the *L. erysimi* population (Equation 2, Table 1). Similarly, excluding SSH (sunshine hours) results in a substantial decrease in R² (0.32), indicating that SSH has a major impact in the population of mustard aphids. However, removing RF (rainfall) did not result in a decrease in R² (0.31), indicating that RF has a negligible effect on *L. erysimi* (Equation 3, Table 1). Additionally, RH1 was eliminated, and the model that included Tmax, Tmin, and RH1 (relative humidity) could only explain 0.23% of the fluctuation in the aphid population, indicating that morning relative humidity plays a substantial impact (Equation 2.4, Table 1). Table 2 displays the observed and anticipated values for the aphid population using a regression model one week before the aphid population. The data clearly shows that the predicted points were closer to the observed data. The RMSE for historical data points was 3.96 aphids, whereas the RMSE for observed data was 4.52 aphids. Aphid population onset after one week is significantly influenced by wind speed and sunlight, according to the regression model's test of significance ($R^2 = 0.71$). Regression analysis of meteorological factors two and three weeks before aphid detection revealed a number of inconsistent data points. Aphid population trends have been impacted by the unpredictable weather that has been witnessed during the last sixteen years. Forecasting for the previous two and three weeks was underestimated because of the model's larger standard error and weaker coefficient of determination. One week, two weeks, and three weeks prior to the same date, there was a significant difference in the R² values. The significant fluctuation in sowing dates and unusual weather circumstances, such as minimum temperature and morning relative humidity, may be the cause of this. Table 1 displays the partial coefficients determination (R²) for these meteorological factors.

Fig. 1: Observed and predicted aphid population with one week before weather parameters (a,b)

The least significant impact of meteorological factors on the same date, two weeks previous, and three weeks prior to population observation is shown by the lowest R² value. However, the minimum temperature has a major impact on population growth during the establishing period. The impact of weather factors one week before to the aphid population measurement is greater than that on the same date, two weeks prior, and three weeks prior. The aphid population was greatly impacted by the minimum temperature and the relative humidity in the morning. The research is consistent with the findings of Dhaliwal et al. (2007), who reported comparable R² values of 0.42.

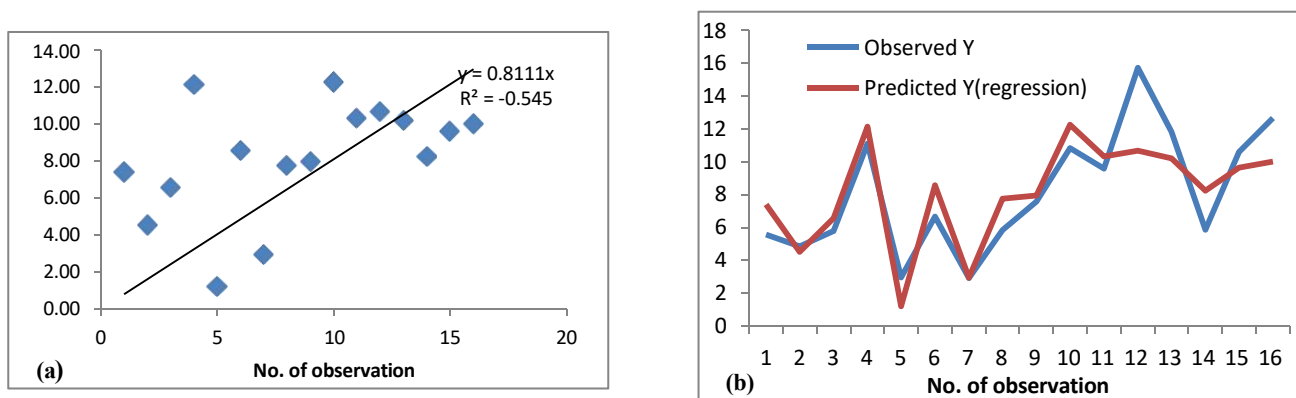


Table 1: Equation developed by taking four time periods of weather variables with aphid population

Eq. no.	Regression equation obtained	R ²	SE	F _{sig}
On same date				
1	Y= 114.56-1.66X ₁ +2.65X ₂ -0.46X ₃ -0.71X ₄ -0.01X ₅ -1.68X ₆ -0.12X ₇	0.57	3.29	0.27
1.1	Y= 112.44-1.66X ₁ +2.61X ₂ -0.44X ₃ -0.71X ₄ -0.02X ₅ -1.68X ₆	0.57	3.12	0.16
1.2	Y= 90.64-2.02X ₁ +2.47X ₂ -0.37X ₃ -0.46X ₄ +0.003X ₅	0.44	3.37	0.24
1.3	Y= 91.12-2.03X ₁ +2.5X ₂ -0.38X ₃ -0.46X ₄	0.44	3.22	0.13
One week before				
2	Y= 31.58+2.08X ₁ -2.76X ₂ -0.87X ₃ +0.65X ₄ -0.03X ₅ -4.5X ₆ +2.13X ₇	0.71	2.72	0.08
2.1	Y= 21.29+2.24 X ₁ -2.59 X ₂ -0.65 X ₃ +0.54 X ₄ +0.03 X ₅ -1.7 X ₆	0.49	3.38	0.2
2.2	Y= 23.42+10.5 X ₁ -1.38 X ₂ -0.55 X ₃ +0.43 X ₄ +0.01 X ₅	0.32	3.71	0.5
2.3	Y= 19.45+1.10 X ₁ -1.42 X ₂ -0.52 X ₃ +0.45 X ₄	0.31	3.56	0.33
2.4	Y= 29.82+1.24 X ₁ -1.36 X ₂ +0.4 X ₄	0.23	3.60	0.33
Two week before				
3	Y= -74.78+1.52X ₁ -1.06X ₂ +0.60X ₃ +0.14X ₄ -0.03X ₅ -1.13X ₆ +0.38X ₇	0.31	4.20	0.80
3.1	Y= -81.26+1.86X ₁ -1.14X ₂ +0.59X ₃ +0.19X ₄ -0.03X ₅ -1.24X ₆	0.30	4.0	0.68
3.2	Y= -48.44+1.49X ₁ -0.69X ₂ +0.16X ₃ +0.28X ₄ -0.05X ₅	0.25	3.9	0.65
3.3	Y= -20.02+1.49X ₁ -0.88X ₂ -0.12X ₃ +0.26X ₄	0.17	3.9	0.69
Three week before				
4	Y= -132.66-0.34X ₁ +0.33X ₂ -0.85X ₃ -0.44X ₄ -0.005X ₅ -1.9X ₆ -1.35X ₇	0.52	3.50	0.38
4.1	Y= 101.43-0.65X ₁ +0.03X ₂ -0.56X ₃ -0.36X ₄ +0.03X ₅ -1.42X ₆	0.41	3.66	0.45
4.2	Y= 103.21-1.16X ₁ +0.28X ₂ -0.65X ₃ -0.23X ₄ -0.02X ₅	0.35	3.64	0.42
4.3	Y= 109.60-1.25X ₁ +0.21X ₂ -0.69X ₃ -0.25X ₄	0.34	3.49	0.28
Where,				
X ₁	Maximum temperature (°C)	X ₅	Rainfall (mm)	
X ₂	Minimum temperature (°C)	X ₆	Sunshine (hours)	
X ₃	Morning relative humidity (%)	X ₇	Wind speed (km/hr)	
X ₄	Evening relative humidity (%)			

Table 2: Observed and predicted aphid population by regression model (R²=0.71)

Observation (Year)	Observed Y	Predicted Y	Residuals
1 (1998-99)	5.58	7.46	-1.88
2 (1999-2000)	4.86	4.54	0.32
3 (2000-01)	5.8	6.70	-0.90
4 (2001-02)	11.1	12.13	-1.03
5 (2002-03)	2.98	2.15	0.83
6 (2003-04)	6.67	8.57	-1.90
7 (2004-05)	2.93	7.44	-4.51
8 (2005-06)	5.86	7.48	-1.62
9 (2006-07)	7.58	10.16	-2.58
10 (2007-08)	10.84	12.81	-1.97
11 (2009-10)	9.58	10.26	-0.68
12 (2010-11)	15.71	10.96	4.75
13 (2011-12)	11.82	10.32	1.50
14 (2012-13)	5.88	7.85	-1.97
15 (2013-14)	10.59	9.57	1.02
16 (2014-15)	12.66	10.01	2.65
RMSE=3.96			
An independent data set(Predicted aphid population)			
17 (2015-16)	14.03	14.09	-0.062
18 (2016-17)	12.31	9.49	2.817
RMSE=4.52			

The population of aphids showed a positive link with afternoon and morning relative humidity and a negative correlation with maximum and minimum temperature, rainfall, wind speed, and evaporation. The high coefficient of determination (R) values (0.92 to 0.99) showed that the meteorological conditions had a significant influence on the mustard aphid population. *L. erysimi* was found to be highly conducive to the following conditions: temperature (maximum 18.7 and minimum 5.0 C), relative humidity (morning 91.5 and evening 50.5 percent), rainfall (000.0 mm), evaporation (below 1.55 mm), bright sunshine hours (below 5.8 hr), and wind speed (below 3.4 km/h) (Hasan and Singh, 2010).

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